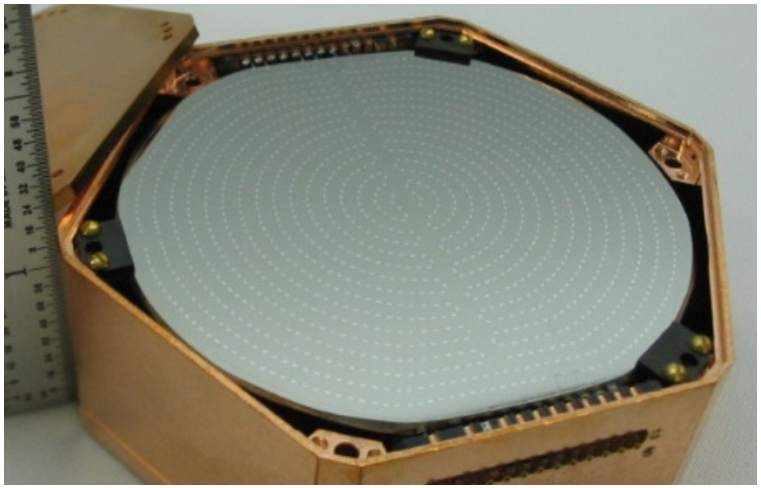
CDMS



Don Holmgren

SCD Projects Meeting

June 19, 2013

Outline

- Introduction (dark matter)
- Online
- Soudan to FNAL data movement
- Offline (from Ben Loer)
- SuperCDMS at SNOLAB (CDMS G2)

A quick introduction to dark matter

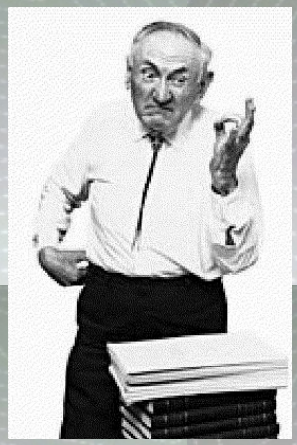
- Slides copied from Lauren Hsu's talks
- For more information, see:
  - Lauren's Fermilab Colloquium Oct 31, 2012
  - Lauren's FPCA Seminar Feb 9, 2012
  - Jeter Hall's FPCA 2010 Retreat Talk
  - SuperCDMS website
  - Dan Bauer's G2 Briefing for the Directorate

An old puzzle…


Coma Galaxy Cluster
(SDSS)

1933:

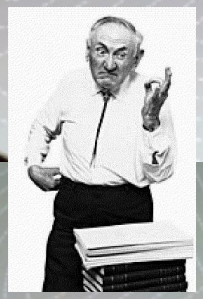
Fritz Zwicky analyzes velocity dispersion in Coma Cluster



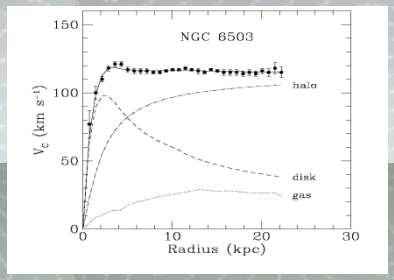
Individual galaxies move too fast for a bound system…

was the cluster more massive than deduced from luminous material?

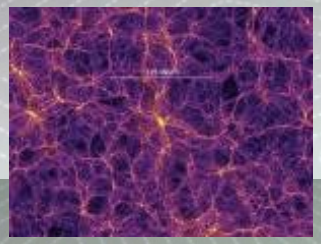
...becomes an established problem



Zwicky discovers missing mass in Coma Cluster



Galactic rotation curves measured with 21cm suggest dark matter on galactic scales

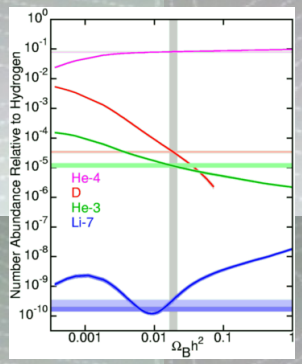


N-body simulations reproduce large scale structure if DM is cold

Bullet Cluster shows separation btwn baryonic matter and center of gravity

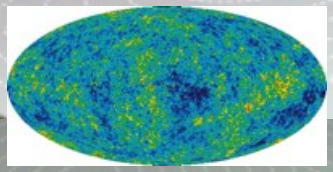
1933 ~1970 ~1975 ~1980 ~1990 2006 TODAY

Astrophysical data tell us much about dark matter but we still don't know its fundamental properties !



BBN sets bound on baryonic matter content of the universe

Gravitational lensing tomography supports existence of DM

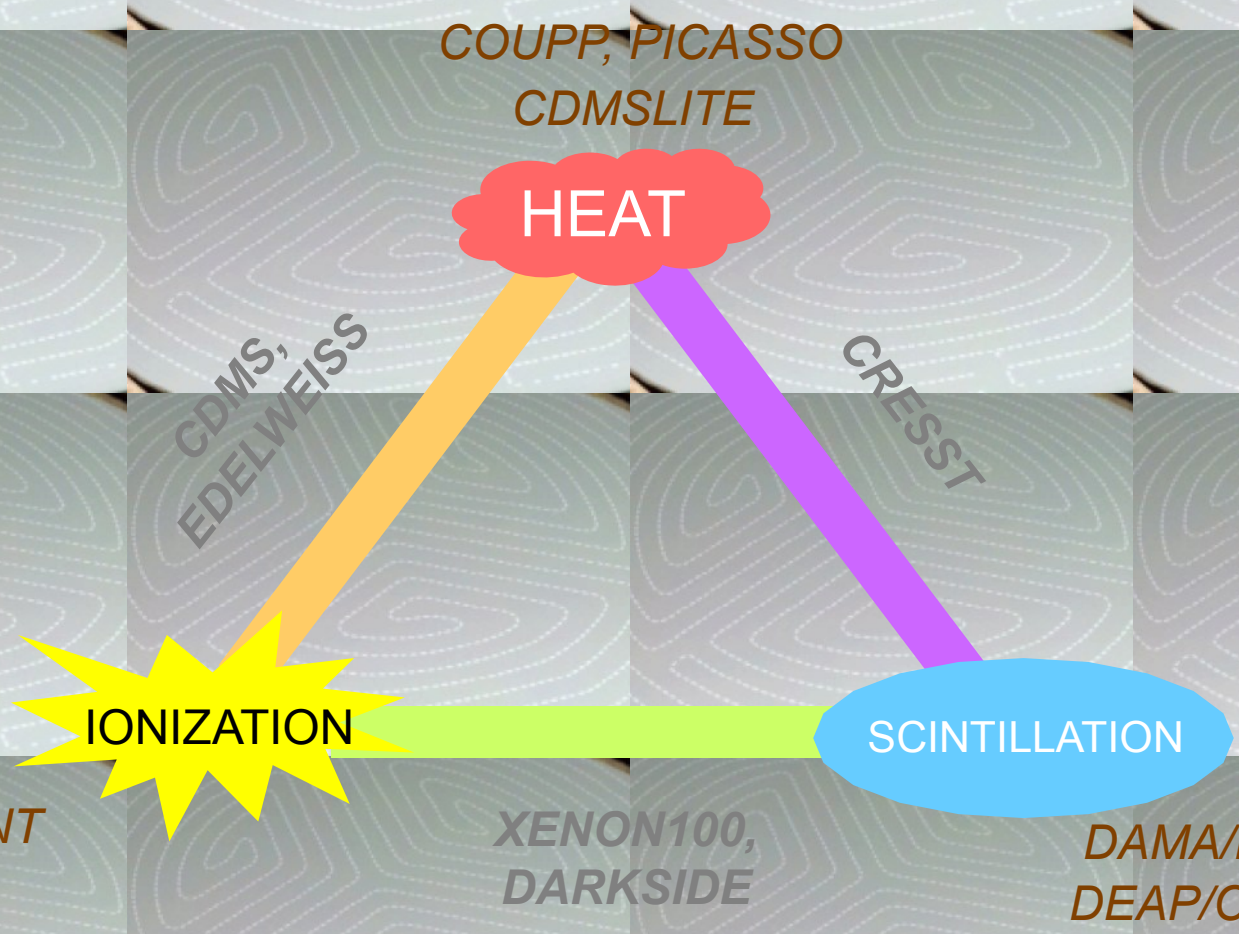


CMB tells us that DM is ~85% of all matter in the Universe, and Ω_{CDM} = 23%

DM Assumptions for Direct Detection

- Dark matter particles …
  - Neither absorb nor emit light (no charge, no EM interactions)
  - Interact with ordinary matter via gravity (infer from astronomical observations) and the weak force (so will cause nuclear recoils)
  - Have large masses compared to standard particles
- Candidate: WIMPs (Weakly Interactive Massive Particles)
- Detect via recoils of suitable target nuclei
  - CDMS detectors operate at low temperature (0.090K) in part because predicted recoil energies are tiny (10-100 KeV)
  - Operate underground to shield from cosmic ray background (background rejection is everything)
  - CDMS detectors can distinguish DM candidates from photons and charged particles, but neutrons will cause similar recoils

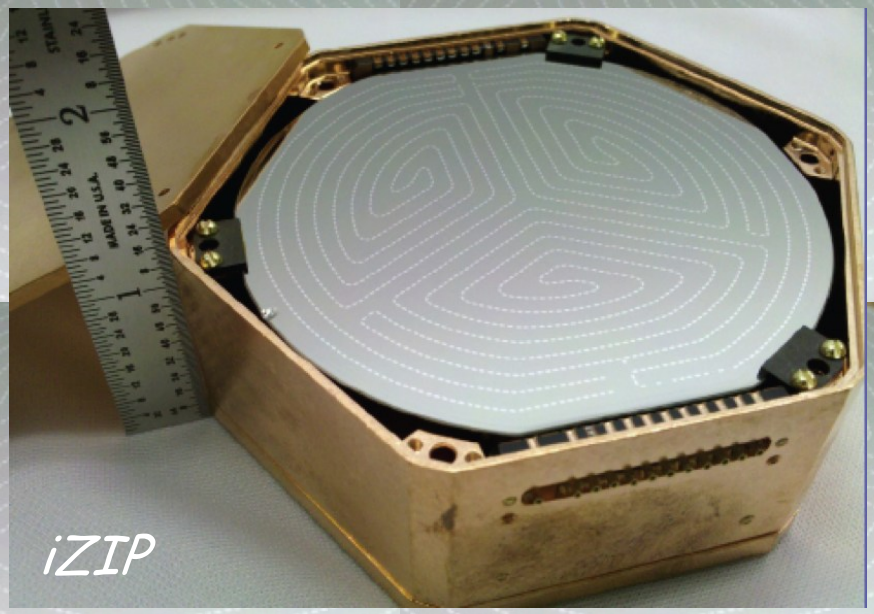
WIMP detection techniques



SuperCDMS Soudan

10 kg of Ge arranged in 5 towers

iZIP = "interleaved Z-sensitive Ionization and Phonon" detector

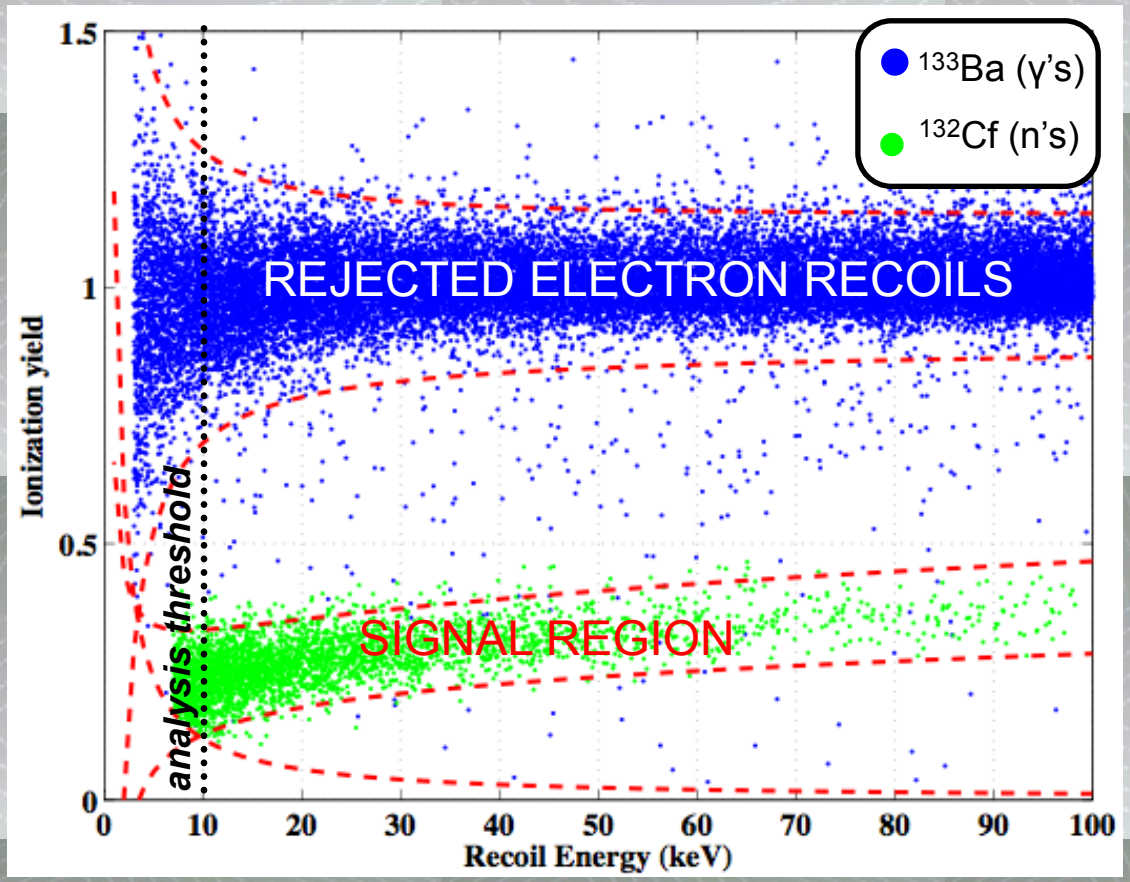


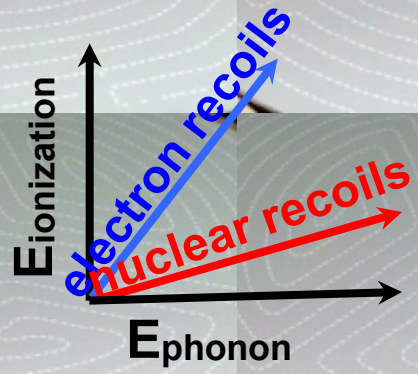
2.5 cm
(thickness of Ge crystals)

0.6 kg per detector

iZIP: 2.5-cm thick, double-sided phonon and charge sensors

How it works for CDMS





$$\text{ionization yield} = \frac{E_{ionization}}{E_{phonon}}$$

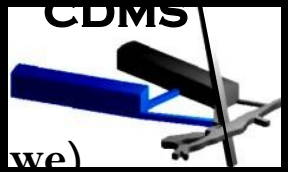
$1{:}10^4$ rejection of gammas based on ionization yield alone…

BETTER THAN $1{:}10^6$ rejection of gammas and betas w/ phonon pulse shape (in CDMSII)

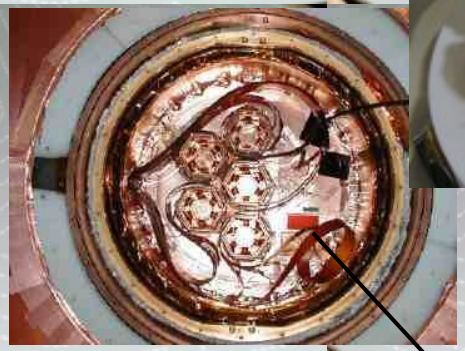
Soudan setup

Surface

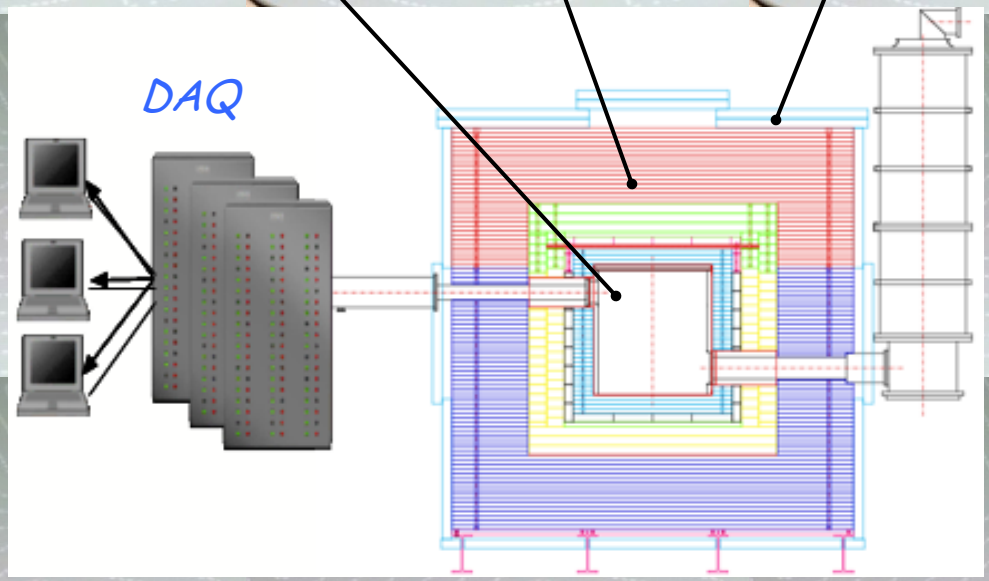
Deep underground site significantly reduces cosmogenic background



Array of 15 Ge detectors reside in the "icebox"



Lead, poly and scintillator provide additional shielding



Cryogenic system cools detectors to ~50 mK, needed for phonon detection

DAQ *(running since Dec 2003)*

- CDMS events consist of digitized traces from the phonon and charge channels from the iZIPs
  - Background running (WIMP-search) also includes digitized muon-veto PMT traces
  - Digitizers are VME-based, as are signal history buffers and GPS clock data
    - Other electronics are in NIM crates, or in CDMS 9U detector and trigger crates
  - Fast readout ("event builder") is *CDMSR2DM*, based on Luciano Piccoli's *R2DM* Run II software
    - Dependencies on ACE, ITC, thread_util, ORBacus
    - Underpinnings have been frozen since RedHat 7, all running on private network (we are already in data preservation mode!!)

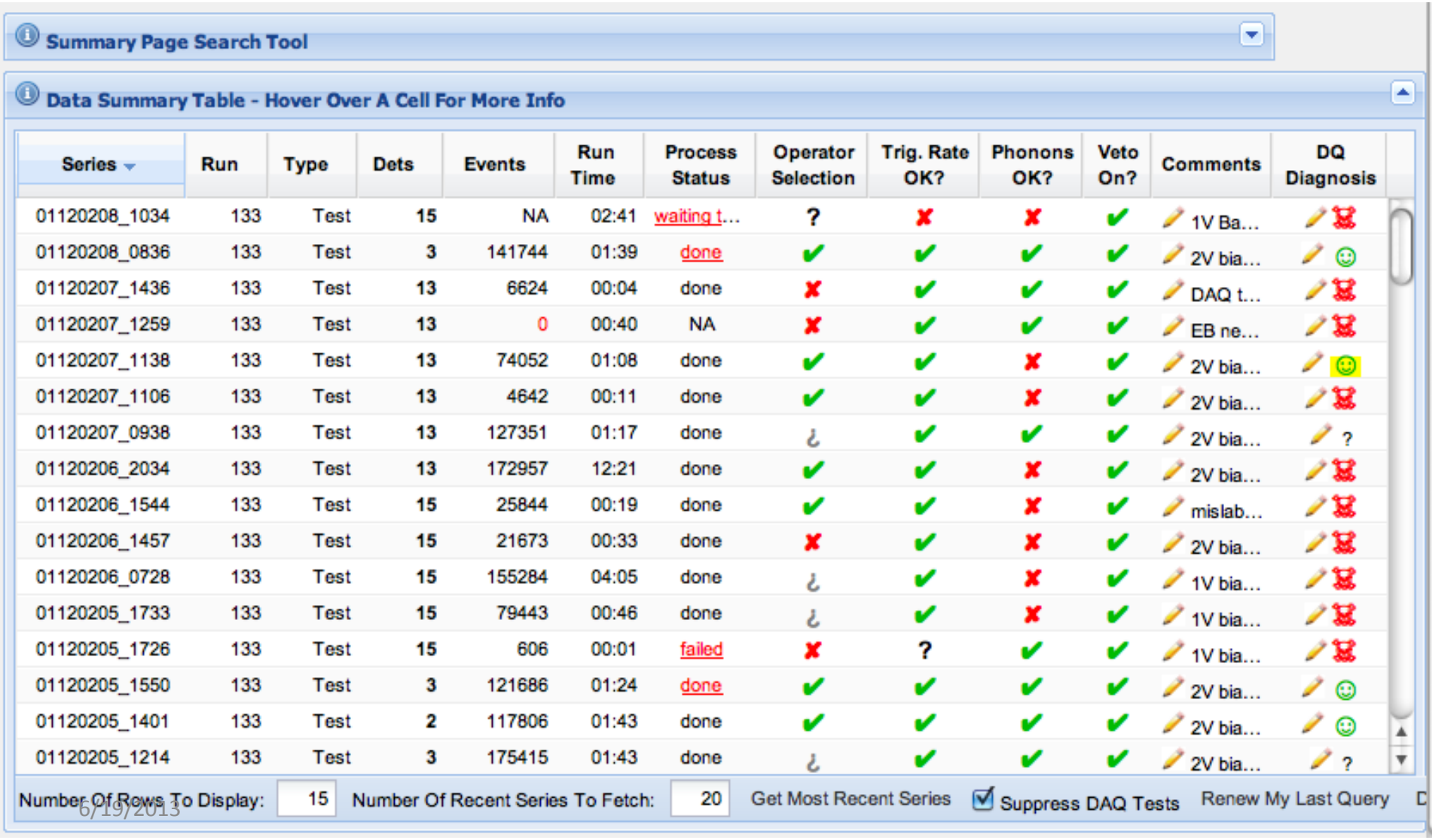
DAQ (cont'd)

- Slow control is Java-based
  - RMI is used for inter-server communications
  - CORBA is used to interact with the event builder, and for various event channels (monitoring, error, state)
- Shifters use a data quality monitoring and reporting framework implemented in Tomcat

- DAQ and other computers at Soudan
  - 7 for event building and slow control
  - 3 disk servers (about 100 TB) for raw data, online processing (data quality system)
  - 3 Windows systems for control of cryogenics

Online Data Quality System

Lets try a live demo: http://cdmsmini.cdms-soudan.org:8080/DQDiagnostics.jsp



Summary Page Search Tool

Data Summary Table - Hover Over A Cell For More Info

Series	Run	Type	Dets	Events	Run Time	Process Status	Operator Selection	Trig. Rate OK?	Phonons OK?	Veto On?	Comments	DQ Diagnosis
01120208_1034	133	Test	15	NA	02:41	waiting t...	?	✘	✘	✔	1V Ba...	
01120208_0836	133	Test	3	141744	01:39	done	✔	✔	✔	✔	2V bia...	
01120207_1436	133	Test	13	6624	00:04	done	✘	✔	✔	✔	DAQ t...	
01120207_1259	133	Test	13	0	00:40	NA	✘	✔	✔	✔	EB ne...	
01120207_1138	133	Test	13	74052	01:08	done	✔	✔	✘	✔	2V bia...	
01120207_1106	133	Test	13	4642	00:11	done	✔	✔	✘	✔	2V bia...	
01120207_0938	133	Test	13	127351	01:17	done	¿	✔	✔	✔	2V bia...	?
01120206_2034	133	Test	13	172957	12:21	done	✔	✔	✘	✔	2V bia...	
01120206_1544	133	Test	15	25844	00:19	done	✔	✔	✘	✔	mislab...	
01120206_1457	133	Test	15	21673	00:33	done	✘	✔	✘	✔	2V bia...	
01120206_0728	133	Test	15	155284	04:05	done	¿	✔	✘	✔	1V bia...	
01120205_1733	133	Test	15	79443	00:46	done	¿	✔	✘	✔	1V bia...	
01120205_1726	133	Test	15	606	00:01	failed	✘	?	✔	✔	1V bia...	
01120205_1550	133	Test	3	121686	01:24	done	✔	✔	✔	✔	2V bia...	
01120205_1401	133	Test	2	117806	01:43	done	✔	✔	✔	✔	2V bia...	
01120205_1214	133	Test	3	175415	01:43	done	¿	✔	✔	✔	2V bia...	?

Number Of Rows To Display: 15 Number Of Recent Series To Fetch: 20 Get Most Recent Series Suppress DAQ Tests Renew My Last Query

Soudan to FNAL Data Movement

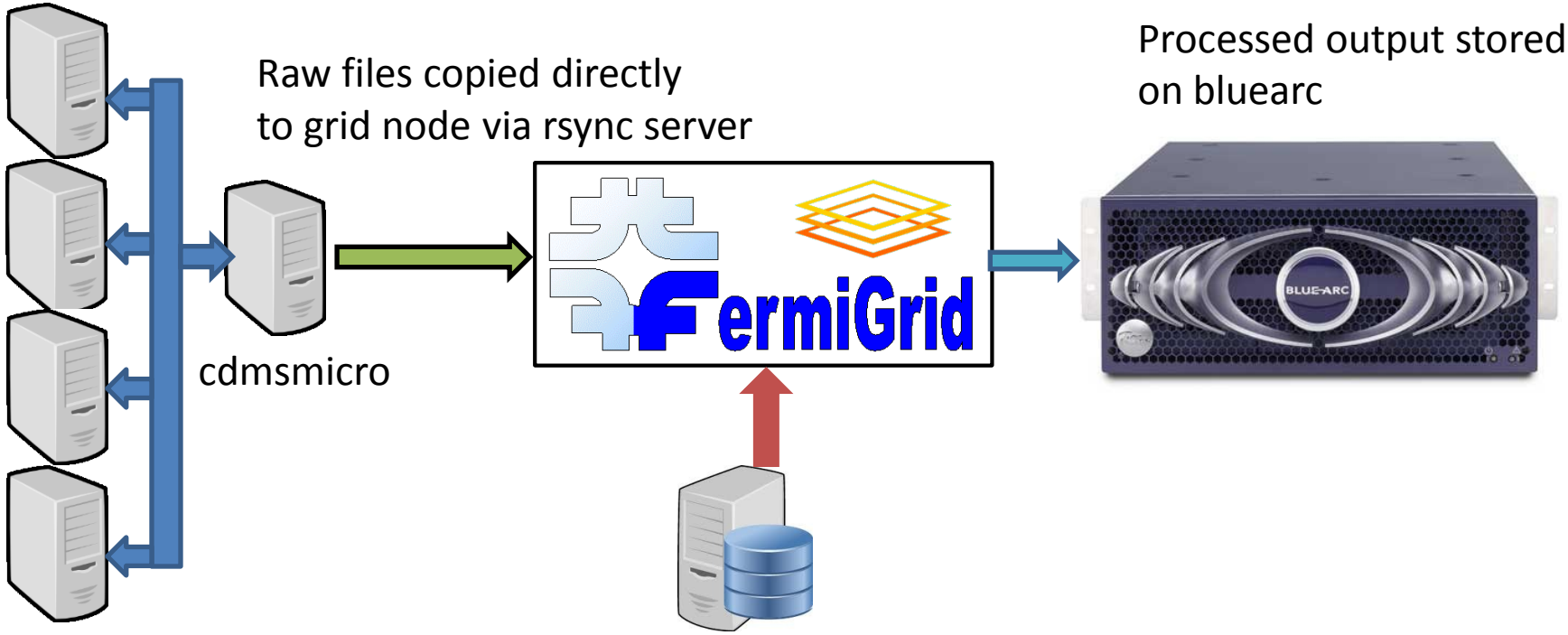
- Data generation rates:
  - Background (WIMP search) – 0.6 MiB/sec
  - Calibration (Barium alpha) – 11 MiB/sec
  - Typical month (experiment runs 24 hours/day):
    - 30 calibration runs totaling 1.5 TiB
    - 210 background runs totaling 0.5 TiB
- Data movement scripts (all implemented in Perl)
  - Evolved from earlier tape archiving framework
  - Data are moved from event builder to online analysis server and copied to Soudan data archive
  - Data archive machine at FNAL pulls (via http) data from Soudan data archive
  - Original data files on the event builder are deleted once copies reside on both the Soudan and FNAL disk archives

CDMS Data at FNAL

- CDMS operates 10 servers in LCC-107
  - About 350 TiB of storage
  - Machines are used for interactive analysis (MATLAB, and ROOT-based)
  - All raw data taken at Soudan (2003 forward) is kept spinning
  - Outputs of processing runs are also spinning
- Enstore
  - All raw data are written redundantly (2 copies, one each in FCC and GCC)
  - Roughly 64 TiB in each building (oldest data were not duplicated)
  - Monthly ingest is 1.9 TiB for each copy

CDMS Data Processing

Raw Data distributed among
several machines,
shared via NFS



CDMS "cluster"
(cdmsatto, 'pico, 'tera, 'mega…)

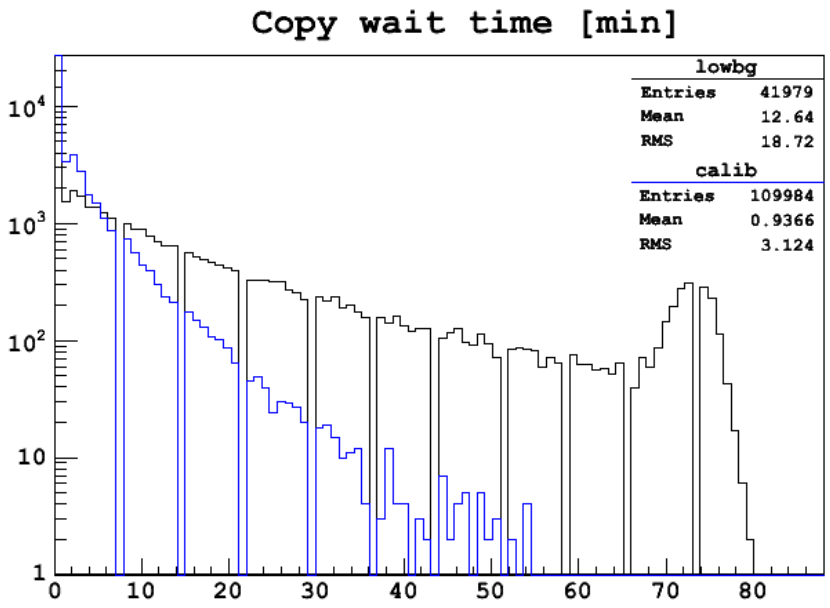
Database
cdmsmini.cdms-soudan.org

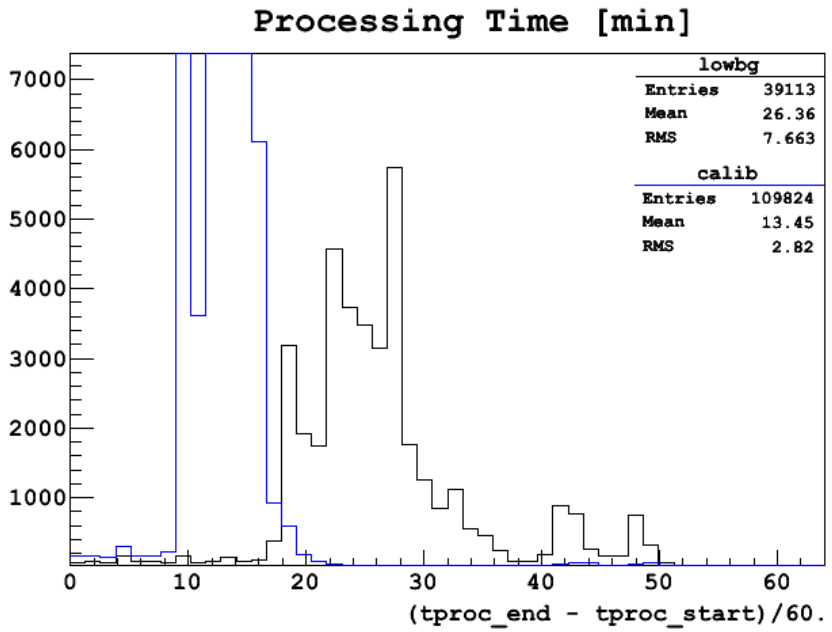
Typical Processing Stats

Full reprocessing done ~2-3 times per year.
Last was April 2013. Smaller batches of ~hundreds of files done ~monthly.

	Calibration	Regular
Batches submitted	27	38
Grid jobs	5100	7735
Job idle time avg	150 min	
Job run time avg	5 hours	
Raw data files	115669	46843
Typical raw file size	100 MB	300 MB
Rsync copy time	1.5 min	7 min
Per-file process time	13 min	26 min

Single rsync server can be major delay! (Is SAM a possible solution?)





Data copy scripts will sleep and retry connection if max rsync clients reached

Can spend more time waiting for data than processing!

Post processing

- After data/logs checked, manually copied back to CDMS NFS cluster
- Only master copy of processed data is at FNAL
- Users copy what they need for a particular analysis to their home institutions (or work remotely)
  - Again, is SAM a good solution for data copy/caching at multiple sites?

CDMS G2 (SuperCDMS at SNOLAB)

- (Planned) Improvements over Soudan SuperCDMS:
  - 9 Kg → 200 Kg
  - 3” Diameter iZIPs → 4” Diameter
  - 180 channels (120 phonon, 60 charge) → 1152 channels (864 phonon, 288 charge)
  - Lowered backgrounds through:
    - Deeper experiment
    - Active neutron veto
    - < 1 background event in 4 years of running!
  - New electronics (FNAL/SLAC) and new unified DAQ (“Midas” – TRIUMPH/UBC/PNNL)

CDMS G2 Challenges

- Data volumes
  - Naïvely, 6.4X the Soudan rate and data volume
    - Roughly 12 TiB per month if the same ratio of background to calibration data sets occurs
  - But, same or smaller network pipes (can't do 12 TiB per month) either out of the mine or to FNAL
  - Possible solutions:
    - Currently on-going iZIP analysis on Soudan data may justify taking much less calibration data
    - May need to do calibration analysis on computers at SNOLAB and only ship RQ files to the surface and FNAL
    - Back to shipping tapes??

CDMS G2 Challenges

- Extensive Soudan analysis software base exists, however:
  - Many opportunities for improvement, particularly implementation of a real data catalog
  - CDMS will explore other Fermilab frameworks
  - A bit early to specify computing needs and schedule
    - Dependent on analysis of Soudan iZIP runs
    - New 4” detectors will need to be characterized to understand if digitization parameters and so data volumes per event will differ from Soudan iZIPs (sampling rate, trace lengths)
    - CDMS G2 depends on DOE down-select this year, and timing will further depend on budgets and continuing resolutions

The End